Teacher Professional Development under NEP 2020: A Structured Narrative Review of Technology-Enabled Practices, Challenges, and Future Directions

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ABSTRACT

The National Education Policy (NEP) 2020 emphasizes the role of technology in shaping teacher professional development (TPD). This review investigates technology-enabled TPD, concentrating on digital competence, the integration of technology and pedagogy, collaborative learning, implementation challenges, equity, and AI-focused professional development. A narrative review of 14 studies identified five key themes. The findings indicate that technology enhances flexibility and access; however, effective TPD necessitates pedagogical integration, collaboration, mentoring, practical application, and institutional support. Barriers such as infrastructure limitations, unequal access, technical difficulties, and contextual differences persist. AI-focused TPD demands AI literacy, ethical awareness, critical evaluation, and pedagogical judgment within a continuous, context-sensitive professional learning process.

Keywords: Teacher Professional Development; NEP 2020; Digital Competence; Educational Technology; Artificial Intelligence.

INTRODUCTION

Technology is changing how teachers' access, participate in, and apply professional learning. Models of teacher professional development (TPD) that are online, blended, asynchronous, and mediated by technology have broadened flexible and accessible opportunities across geographical and temporal boundaries. Empirical studies, along with recent systematic reviews and meta-analyses, demonstrate that such TPD can enhance teachers' knowledge, self-efficacy, and classroom practice, particularly when it is linked to practical activities, interaction, and opportunities for application in authentic contexts (Tzovla et al., 2021; Huang et al., 2024; Bansal & Sharma, 2024; Rathnabai, 2024; Kohnke et al., 2024; Morina et al., 2025; Stavermann, 2025). However, this evidence consistently indicates that participation in technology-enabled TPD does not inherently result in meaningful pedagogical integration. Many teachers remain more adept at operating digital tools than at using them purposefully to support learning objectives, instructional strategies, or classroom contexts (Subaveerapandiyan & Nandhakumar, 2021; Priyamvada & Deepshikha, 2024; Amemasor et al., 2025). Therefore, digital competence should be understood not only as technical proficiency but also as the ability to determine how, when, and why technology should be employed for specific pedagogical purposes, supported by sustained professional learning that explicitly connects technology with pedagogy, subject knowledge, and classroom practice.

Further evidence suggests that professional learning is a social and practice-oriented process, whose quality and sustainability depend on collaboration, mentoring, reflection, peer learning, and opportunities for classroom application. Studies indicate that stronger technology integration is associated with participation in professional learning communities and mentoring, and that online forums and reflective activities can assist

teachers in adapting generalized content to their own classroom realities (Tzovla et al., 2021; Uştuk, 2022; Sinha, 2025). Nonetheless, access to and participation in technology-enabled TPD remain uneven, influenced by infrastructure, connectivity, device availability, affordability, time, technical assistance, and institutional support, with significant disparities between rural and urban contexts in India and internationally (Priyamvada & Deepshikha, 2024; Gu et al., 2025). In India, these issues are particularly salient under the National Education Policy (NEP) 2020, which places continuous professional development, digital resources, and technology integration at the core of teacher-education reform, while evidence still highlights a persistent gap between policy aspirations and classroom-level implementation. The rapid emergence of artificial intelligence (AI) adds further complexity, as AI-focused TPD begins to address AI literacy, ethics, bias, and critical pedagogical use, expanding the notion of digital competence and introducing new demands on teachers' judgment and professional responsibility (Ravi et al., 2023; Tan et al., 2025; Lademann et al., 2025).

In this context, the present review examines technology-enabled teacher professional development within the framework of NEP 2020, treating TPD as a continuous professional-learning process in which technology, digital competence, pedagogy, collaboration, and institutional conditions interact. It synthesizes evidence across five interconnected dimensions that emerge from the literature: technology-enabled and flexible professional learning; digital competence and technology–pedagogy integration; collaborative and practice-oriented professional learning; implementation challenges and equity; and emerging AI-focused professional development

This study was guided by the following research questions:

RQ1. What forms of technology-enabled and flexible teacher professional development are reported in the literature, particularly in relation to online, blended, asynchronous, MOOC-based, and microlearning approaches?

RQ2. What evidence is available regarding teachers' digital competence and the integration of technology with pedagogy through technology-enabled professional development?

RQ3. How do collaboration, mentoring, professional learning communities, reflection and classroom application contribute to technology-enabled teacher professional development?

RQ4. What infrastructural, technological, institutional and contextual challenges influence teachers' participation in and equitable access to technology-enabled professional development?

RQ5. What emerging evidence is available on AI-focused teacher professional development, particularly in relation to AI competency, AI literacy, ethical awareness and pedagogical application?

METHODOLOGY

This research conducted a structured narrative literature review to explore the role of technology-enabled teacher professional development (TPD) within the framework of the National Education Policy (NEP) 2020. The primary aim was to analyse the increasing incorporation of technology in teachers' professional learning and to pinpoint the opportunities, challenges, and conditions that affect its practical application. Given the diversity in educational contexts, professional development strategies, research methodologies, and outcomes reported in studies on technology-enabled TPD, a narrative approach was selected to synthesize the available evidence and discern recurring themes in the literature.

The review covered the period from 2020 to 2025, emphasizing technology-enabled and flexible professional learning, digital competence, integration of technology with pedagogy, collaboration, implementation challenges, equity, and the emergence of AI-focused professional development. The goal was to construct a comprehensive understanding of how technology facilitates teacher professional learning and the conditions under which such learning can enhance classroom practice.

Data collection

Research conducted on literature from 2020 to 2025 utilized Scopus, ERIC, and Google Scholar. This investigation was further enriched by examining pertinent government and institutional documents related to NEP 2020, teacher education, digital education, and professional development. Additionally, reference lists from relevant publications were scrutinized to identify further sources pertinent to the review's objectives. The search concentrated on literature concerning teacher professional development and technology-enabled learning, encompassing online, blended, asynchronous, MOOC-based, and microlearning methodologies. Related topics included digital competence, technology–pedagogy integration, professional learning communities, mentoring, collaboration, classroom application, implementation challenges, equity, and artificial intelligence.

The initial search yielded 35 records. These records were evaluated against the review's focus and objectives, resulting in the retention of 14 publications for in-depth analysis. Publications were deemed relevant if they addressed teacher professional development or teacher education in relation to technology-enabled learning, digital competence, pedagogical integration, collaborative professional learning, implementation conditions, equity, or AI-focused teacher development. Evidence from both Indian and international contexts was considered to provide a comprehensive understanding of the subject and to explore issues pertinent to the implementation of technology-enabled teacher professional development under NEP 2020.

Data analysis

The selected publications were subjected to a narrative thematic synthesis to discern recurring patterns, similarities, differences, and context-specific insights related to technology-enabled teacher professional development. The analysis concentrated on the interplay between professional-learning formats, teachers' digital competence, pedagogical application, collaborative support, and the conditions influencing participation and implementation. Furthermore, the study explored the emerging role of AI in teacher professional development, focusing on AI literacy, ethical awareness, critical evaluation, and pedagogical judgment. The synthesis identified five interconnected themes: (1) technology-enabled and flexible professional learning; (2) digital competence and technology–pedagogy integration; (3) collaborative and practice-oriented professional learning; (4) implementation challenges and equity; and (5) emerging AI-focused professional development. These themes form the organizing framework for the Results section.

Data Reduction

Fourteen publications meeting the review's relevance criteria were retained for detailed comparison. The information extracted from each publication included author and year, study focus, method or evidence source, and principal findings related to technology-enabled teacher professional development. The summary below provides an overview of the literature informing the five themes reported in the Results section.

Table 1. Summary of the Reviewed Literature

Author(s) and year	Study	Method and data collection / evidence source	Main findings
Amemasor et al. (2025)	Relationships among school digital preparedness, digital professional development, professional learning communities, and digital instructional	Quantitative study involving 188 STEM teachers and 11 headteachers across 11 senior high schools; relationships were analysed using partial least squares structural equation modelling.	Digital preparedness alone did not ensure classroom integration; digital professional development and professional learning communities were important indirect pathways linking readiness with instructional use.

	integration in Ghana.		
Gu et al. (2025)	Comparison of online teacher professional development, policy implementation, infrastructure, participation, and equity in the United States and China.	Comparative case study drawing on structured surveys, semi-structured interviews, policy-document analysis, and accounts from teachers, policymakers, and programme developers.	Reported participation rates of 85% in the United States and 75% in China by 2024, alongside high perceived effectiveness; access and equity remained uneven, particularly across rural and urban contexts.
Lademann et al. (2025 preprint)	Four-week training programme on AI in everyday school and classroom practice for German teachers.	Pre–post evaluation of a blended course combining synchronous and asynchronous learning, webinars, workshops, and practical projects; AI literacy data covered 291 teachers and attitude data 436 teachers.	Reported AI-literacy scores rose from 13.15 to 15.13 ($p < .001$), with more positive attitudes toward AI integration; this source is the 2025 preprint relevant to the review period.
Sinha (2025)	Technology-focused teacher professional development models and implementation conditions across India.	Mixed-methods convergent parallel design comprising five programme case studies, semi-structured interviews with 15 stakeholders, and an online survey of 287 teachers across 12 states.	Most surveyed teachers applied less than half of the practices introduced; stronger integration was associated with mentoring and professional learning communities, while rural teachers reported device and connectivity barriers.
Tan et al. (2025)	Intelligent-TPACK professional development to strengthen university teachers' AI competency.	Six-month intervention with 125 university teachers, including intervention and control groups and pre-/post-intervention competency measurement.	AI competency improved significantly in the intervention group; the findings support integrating AI knowledge with pedagogical and content-related judgement.
Bansal and Sharma (2024)	Online in-service teacher training for designing lesson plans using instructional techniques based on learning theories.	Mixed-method pre-test–post-test intervention with 26 school teachers. Evidence included lesson-plan ratings before and after training, a 16-item rating rubric, and focused group interviews.	Reported improvements in lesson planning, instructional strategies, use of open educational resources, online discussion, and articulation of learning objectives.
Choudhury (2024)	NEP 2020 and quality enhancement in teacher education, including continuous	Descriptive survey drawing on primary and secondary sources; a Google Forms questionnaire was sent to	Provided Indian policy and implementation context on teacher-education reform, CPD, technology integration, infrastructure, funding, and institutional readiness; it was used

	professional development and technology integration.	teacher-education institutions.	as contextual evidence rather than as an evaluation of NEP 2020 overall.
Kohnke et al. (2024)	Microlearning as professional development for higher-education English-language teachers working in online and blended learning.	Two-stage exploratory design: questionnaire survey of 67 teachers followed by semi-structured interviews with 12 participants after the microlearning activities.	Teachers perceived short learning activities as flexible, autonomous, and relevant; the study also highlighted the need to balance flexibility with collaboration and interaction.
Priyamvada and Deepshikha (2024)	K–12 teachers' perceptions, awareness, and use of educational-technology tools in India.	Small-scale pilot survey of 50 in-service teachers from government and private schools, supplemented by qualitative responses about technology use and barriers.	Reported awareness of Ed-Tech tools (76.9%), use during teaching (92%), and related training (69.2%); infrastructure, affordability, technical, and ethical concerns remained.
Rathnabai (2024)	Development of teachers' competencies for integrating content, pedagogy, and ICT through the ICT in Education Curriculum for School System.	Reflective account of a blended teacher-development curriculum, including pilot activity in NCERT demonstration schools and implementation in Karnataka.	Emphasised hands-on practice, peer review, digital-content creation, ethical ICT use, mentoring, and follow-up; reported classroom technology use rising from 41.16% to 75.22% over two years.
Ravi et al. (2023)	Teachers' experiences of implementing an AI-literacy curriculum in middle-school classrooms.	Qualitative study of seven teachers using eight recorded semi-structured interviews after curriculum implementation; teachers also received ongoing professional development and weekly debriefings.	Teachers reported improved understanding of AI concepts, applications, bias, and ethics; challenges included technical difficulties, limited preparation time, and differences in prior knowledge.
Uştuk (2022)	MOOCs as digital professional-learning spaces for pre-service English-as-a-foreign-language teachers in Turkey.	Qualitative netnographic multiple-case study of two pre-service teachers, drawing on learner diaries, mentoring-session recordings, assignments, forum contributions, and semi-structured interviews.	MOOC content could be insufficiently situated in classroom realities; self-regulation, mentoring, guided reflection, and contextual adaptation helped participants make use of the learning.

Subaveerapandiyan and Nandhakumar (2021)	Teacher educators' ICT skills and online-teaching experience during the pandemic in India.	Online questionnaire completed by 201 respondents drawn from Indian universities and institutions; quantitative analysis included descriptive statistics, ANOVA, and independent-samples t-tests.	Many respondents had intermediate computer skills but continued to report difficulties with unfamiliar technologies, online-content development, online assessment, and technical support.
Tzovla et al. (2021)	Five-week asynchronous MOOC for in-service elementary teachers on teaching biological concepts with digital content and open educational resources.	Experimental comparison of teachers who completed the MOOC (127) with a comparison group (39); teaching self-efficacy was measured using the bio-STEBI-A instrument.	The participating teachers showed higher self-efficacy than the comparison group; the MOOC included self-assessment, discussion forums, reflection, and classroom-activity design.

RESULTS

Technology-Enabled and Flexible Professional Learning

The reviewed publications describe a range of technology-mediated formats, including online programmes, blended professional development, asynchronous MOOCs, and short microlearning activities. In India, Bansal and Sharma (2024) reported that a six-week online in-service programme supported improvements in lesson planning, instructional strategies, use of open educational resources, online discussion, and the formulation of learning objectives. Rathnabai (2024) described a more composite blended model that combined face-to-face sessions with online activity, hands-on practice, peer review, digital-content creation, mentoring, and follow-up. Classroom technology use in that programme increased from 41.16% to 75.22% over two years.

International findings point to similar benefits but also illustrate variation in what is measured. Tzovla et al. (2021) reported higher self-efficacy among teachers completing a five-week asynchronous MOOC than among the comparison group. Kohnke et al. (2024) found that short microlearning activities were perceived as flexible, autonomous, and relevant to teachers' immediate professional needs. Gu et al. (2025) reported online TPD participation rates of 85% in the United States and 75% in China, alongside high perceived effectiveness. These outcomes are not directly interchangeable: some concern perceived usefulness or participation, while others concern reported changes in lesson planning, self-efficacy, or classroom technology use. Taken together, they suggest that technology broadens the available modes of professional learning, while the strongest practical value is associated with opportunities to apply learning to teaching.

Digital Competence and Technology–Pedagogy Integration

A recurring distinction across the literature is the gap between being familiar with digital tools and being able to integrate them purposefully into teaching. Subaveerapandiyan and Nandhakumar (2021) reported that many teacher educators possessed at least intermediate computer skills but continued to experience difficulties with unfamiliar technologies, online-content development, and assessment. Priyamvada and Deepshikha (2024) likewise reported considerable awareness and use of educational technology among K–12 teachers while identifying uneven training and a group of teachers with limited or no experience using technology in classrooms. The findings caution against treating awareness or reported use as sufficient indicators of pedagogical competence.

Kohnke et al. (2024) found that teachers valued understanding not only how a technology operated but also its pedagogical utility and adaptability to their own contexts. Amemasor et al. (2025) similarly indicated that digital preparedness alone was insufficient to ensure digital instructional integration; professional development and professional learning communities were important parts of the relationship. The theme therefore points to digital competence as a combination of operational skill, pedagogical reasoning, subject-related judgement, and contextual adaptability. Professional development is more likely to support meaningful integration when it addresses why and when a tool is educationally appropriate, rather than only demonstrating how to use it.

Collaborative and Practice-Oriented Professional Learning

The reviewed evidence places collaboration and classroom application at the centre of continuing professional learning. Sinha (2025), drawing on five technology-focused TPD cases and survey evidence from 287 teachers across 12 Indian states, reported that most teachers implemented less than half of the technology-related practices introduced during professional development. Greater integration was associated with professional learning communities and mentoring, indicating that exposure to new practices does not necessarily result in their sustained use. The reported completion rates also favoured a blended model over fully online or purely face-to-face formats, although this finding should be interpreted in the context of the particular cases examined.

Other studies illustrate mechanisms through which interaction can support practice. Discussion forums in the Tzovla et al. (2021) MOOC facilitated peer teaching, knowledge sharing, and joint problem-solving. Uştuk (2022) found that generalized MOOC content could be poorly aligned with preservice EFL teachers' classroom realities, but mentoring and guided reflection helped teachers adapt course ideas to their settings. Gu et al. (2025) highlighted formative feedback, peer learning, mentoring, active learning, classroom practice, self-directed learning, and reflection as important features of online TPD. Across these studies, the focus shifts from delivery mode alone to the support structures that help teachers interpret, adapt, rehearse, and sustain what they learn.

Implementation Challenges and Equity

The literature identifies infrastructure and access as persistent constraints on participation in technology-enabled TPD. In the Indian evidence, Sinha (2025) reported internet outages and a lack of dedicated devices among rural teachers. Priyamvada and Deepshikha (2024) identified infrastructure deficits, financial constraints, and technical difficulties, while Subaveerapandiyan and Nandhakumar (2021) reported problems involving unreliable internet, communication software, access to specialized software, online assessment, unfamiliar technologies, and support. Together, these findings suggest that an online offer does not in itself ensure that teachers can participate consistently or use the tools confidently.

The equity dimension is particularly visible in Gu et al. (2025), where rural teachers reported lower participation, internet and device access, and perceived equity than urban teachers. Kohnke et al. (2024) also identified the lack of suitable programmes and scheduling conflicts as barriers to participation. These constraints are technological, organizational, and contextual: connectivity and devices matter, but so do affordability, workload, time, programme relevance, technical assistance, and institutional support. Equity therefore requires more than nominal platform access; it requires practical conditions that enable teachers to participate and translate learning into their professional work.

Emerging AI-Focused Professional Development

The AI-focused publications suggest that teacher professional development is expanding beyond conventional digital-tool training towards AI literacy, ethical awareness, critical evaluation, and pedagogical judgement. Ravi et al. (2023) reported that an AI-literacy curriculum supported by ongoing professional development and weekly debriefings strengthened participating teachers' understanding of AI concepts, applications, bias, and ethics. The study also identified practical constraints, including technical difficulties, limited preparation time, and variation in prior knowledge, demonstrating that AI-related learning has its own implementation demands.

Tan et al. (2025) reported significant improvement in AI competency following a six-month Intelligent-TPACK intervention for university teachers. Lademann et al. (2025) reported in a preprint available within the review period that a four-week online course was associated with an increase in AI-literacy scores from 13.15 to 15.13 ($p < .001$) and more positive attitudes towards AI integration. The evidence is promising but remains varied in participant groups, programme design, and outcomes, and the studies do not establish a single model that can be applied universally. The findings instead point to a need for professional development that combines knowledge of AI tools with critical evaluation, ethical reasoning, and context-sensitive pedagogical application.

Across the five themes, a consistent pattern emerges: technology can widen access to professional learning, but the value of that access depends on how learning is connected to pedagogical purposes, peer interaction, mentoring, classroom experimentation, and supportive institutional conditions. The findings should be interpreted as a narrative synthesis of the selected publications rather than as proof of one uniform causal effect.

DISCUSSION

This review highlights the critical role of technology in teacher professional development (TPD), asserting that its impact extends beyond mere access to digital platforms or online courses. Research demonstrates that online, blended, and asynchronous formats enhance flexibility, accessibility, and self-directed learning (e.g., Bansal & Sharma, 2024; Rathnabai, 2024; Tzovla et al., 2021; Kohnke et al., 2024; Gu et al., 2025). However, digital delivery alone does not ensure lasting professional transformation; therefore, technology should be integrated into a comprehensive professional-learning framework rather than being viewed as an isolated solution.

A common observation is the gap between TPD participation and its application in the classroom. Sinha (2025) reported that most teachers implemented less than half of the technology-related practices introduced, with improved integration linked to professional learning communities and mentoring. Uştuk (2022) observed that MOOC content was beneficial only when accompanied by reflection and guidance. These studies underscore that post-training conditions such as collaboration, mentoring, feedback, and practical experimentation are crucial for the effectiveness of technology-enabled TPD.

Evidence regarding digital competence supports this perspective. Although studies in India and globally have documented familiarity with digital tools (Subaveerapandiyan & Nandhakumar, 2021; Priyamvada & Deepshikha, 2024), teachers faced challenges in online content development, assessment, and pedagogical integration. Participants valued understanding the pedagogical utility of technologies and their adaptation to specific subjects and contexts (Kohnke et al., 2024; Amemasor et al., 2025). The findings suggest that digital competence should encompass technical skills as well as pedagogical and contextual judgment, cultivated through professional learning communities. Implementation and equity issues, including infrastructure, connectivity, devices, finances, scheduling, and rural-urban disparities (Sinha, 2025; Gu et al., 2025; Kohnke et al., 2024; Priyamvada & Deepshikha, 2024), hinder access and application despite NEP 2020 (e.g., Choudhury, 2024). AI-focused TPD enhances competence but raises ethical and access concerns (Ravi et al., 2023; Tan et al., 2025; Lademann et al., 2025).

In conclusion, the review suggests that technology-enabled TPD should be conceptualized as an ongoing, socially and institutionally embedded professional-learning process. While technology can expand access and flexibility, its educational value depends on pedagogical integration, collaborative and practice-oriented learning, mentoring, contextual relevance, and supportive institutional conditions. The limited evidence on long-term classroom implementation, student outcomes, and sustainability underscores the necessity for longitudinal, context-sensitive, and impact-focused research on technology-enabled and AI-related TPD**.**

Implications

The findings of this review have significant implications for the design and implementation of teacher professional development (TPD) under the National Education Policy (NEP) 2020. It is recommended that

technology-enabled TPD be conceptualized as context-sensitive, practice-oriented, and sustained professional learning, rather than as brief, technology-centric training. Emphasis should be placed on mentoring, collaborative learning, feedback, and opportunities for teachers to apply new knowledge in classroom settings. Teacher education institutions and TPD providers must account for variations in teachers' digital competence, institutional resources, and local conditions when designing professional development programmes, especially in rural and resource-constrained environments. At the policy level, investment in digital infrastructure should be complemented by adequate technical support, mentoring, and equitable access to professional learning opportunities. Furthermore, with the increasing integration of artificial intelligence (AI) in education, TPD should incorporate AI literacy, ethical awareness, and critical pedagogical judgment, rather than focusing solely on the operation of digital tools. Overall, the findings indicate that enhancing technology-enabled TPD under NEP 2020 necessitates alignment between teachers' professional needs, pedagogical practices, institutional support, and the technological conditions in which professional learning occurs.

CONCLUSION AND FUTURE RESEARCH

This review has analysed the literature concerning teacher professional development (TPD) under the National Education Policy (NEP) 2020, with a focus on technology-enabled practices, digital competence, implementation challenges, and emerging directions. The findings reveal that while technology has enhanced the flexibility and accessibility of professional learning, effective TPD requires more than mere digital access.

Meaningful professional development is linked to the integration of technology and pedagogy, practical application, collaboration, mentoring, contextual relevance, and institutional support. The evidence thus suggests that technology-enabled TPD should be perceived as an ongoing professional learning process rather than a specific training mode.

The review also underscores a persistent gap between participation in professional development and the application of learning in classroom practice. Factors such as infrastructure limitations, unequal access, limited technical support, and varying teacher contexts continue to influence the implementation of technology-enabled TPD. Additionally, emerging AI-related professional development introduces new requirements concerning ethical awareness, critical evaluation, and pedagogical judgment. Therefore, the broader challenge for NEP 2020 is not merely to expand technology-based training but to create conditions that enable teachers to utilize professional learning meaningfully and sustainably.

Future research should aim to strengthen empirical evidence on the long-term transfer and sustainability of technology-enabled TPD. Longitudinal studies could investigate whether improvements in digital competence, self-efficacy, and professional practice are sustained over time and whether they lead to observable changes in classroom practice and student learning. Further research is also necessary across diverse Indian contexts, particularly in rural and resource-constrained settings, different states, and institutional types, where access and implementation conditions may vary significantly.

The literature also indicates the need to compare different TPD models, including blended learning, mentoring, professional learning communities, microlearning, and AI-focused professional development, to determine which approaches are most effective under specific conditions. Such research would provide stronger evidence for the continued development and implementation of technology-enabled teacher professional development under NEP 2020.

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